MASTER OF SCIENCE
IN
COMPUTER SCIENCE

**AGENT-BASED SIMULATION OF A MARINE INFANTRY SQUAD IN
AN URBAN ENVIRONMENT**

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This thesis research focused on the design, development and implementation of an agent based simulation of a Marine infantry squad in an urban environment. The goal was to design an autonomous-agent framework that could model a combatant's decision cycle. A squad entity comprised of these agents was created to explore the idea of team dynamics and the balance between meeting individual goals and team goals. The agents were placed in a two-dimensional, discrete-state, simulation world with a simple model of urban infrastructure. The squad goal was to patrol through the environment using checkpoints. The individual agent goals were to move to a destination and maintain the squad formation. The critical issues of agent movement were collision detection/avoidance, goal managing and forward planning. Distinguishing the agents by their role in the squad allowed a single agent to act as the squad leader. This agent was given the ability to plan a path to accomplish the squad's overall goal as a series of sub-goals, which was successful in getting the majority of the agents to their checkpoints in squad formation. The design of the simulation program facilitates further research in using autonomous agents to model small-units in an urban environment.

**SOFTWARE TESTING TOOLS: METRICS FOR MEASUREMENT OF EFFECTIVENESS ON
PROCEDURAL AND OBJECT-ORIENTED SOURCE CODE**

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The levels of quality, maintainability, testability, and stability of software can be improved and measured through the use of automated testing tools throughout the software development process. Automated testing tools assist software engineers to gauge the quality of software by automating the mechanical aspects of the software-testing task. Automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Evaluating available tools and selecting the most appropriate suite of tools can be a difficult and time-consuming process. In this thesis, a suite of objective metrics is proposed for measuring tool characteristics, as an aide in systematically evaluating and selecting automated testing tools. Future work includes further research into the validity and utility of this suite of metrics, conducting similar research using a larger software project, and incorporating a larger set of tools into similar research.

COMPUTER SCIENCE

WEB-BASED TESTING TOOLS FOR ELECTRICAL ENGINEERING COURSES
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This thesis presents a distance-learning tool, which provides a self-sufficient application that allows one to implement online courses for electrical engineering. A major emphasis is placed on replacing simplistic multiple-choice or true-false test questions. A system named, Distance Learning Tools for Online Tests (DLTOT) is designed, modeled and implemented.

The implementation is based on the Java programming language, using Servlets and Java Server Pages (JSP), three-tier technology and Commercial-Off-The-Shelf (COTS) products, namely, an Apache web server, Tomcat Application server, Microsoft Access, Mathematica, WebMathematica and JSP/Servlet technology.

DLTOT is able to control student access, to allow interaction with the student during the course, and to present a challenging test, which is easily graded by the application itself.

ANALYZING THREADS AND PROCESSES IN WINDOWS CE
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Windows CE 3.0, also known as Pocket PC for palm-sized devices, is becoming increasingly popular among professionals and corporate enterprises. It is estimated that by 2004 Windows CE will have a share of 40% of the marketplace for palm-sized devices. The documented vulnerabilities against a major competitor of WinCE, Palm, and the proliferation of palm-sized devices highlight the need for security for these small-scale systems. This thesis is part of a larger project to enhance the security in WinCE.

This thesis analyzed the threads and processes in WinCE, and discusses authentication, public key infrastructure (PKI) and future technologies as each relates to WinCE. The research discovered that *Taliske*r, the next generation of WinCE, supports Kerberos an authentication protocol, and it also supports PKI (a key management system) components. Results of this thesis show that security can be enhanced in WinCE without requiring a change to its code base.

INTEGRATED DEVELOPMENT ENVIRONMENT (IDE) FOR THE CONSTRUCTION OF A FEDERATION INTEROPERABILITY OBJECT MODEL (FIOM)
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Advances in computer communications technology, the recognition of common areas of functionality in related systems, and an increased awareness of how enhanced information access can lead to improved capability, are driving an interest toward integration of current stand-alone systems to meet future system requirements. However, differences in hardware platforms, software architectures, operating systems, host languages, and data representation have resulted in scores of stand-alone systems that are unable to interoperate properly.

Young's Object Oriented Model for Interoperability (OOMI) defines an architecture and suite of software tools for resolving data representational differences between systems in order to achieve the desired system interoperability. The Federation Interoperability Object Model (FIOM) Integrated Development Environment (IDE) detailed in this thesis is a toolset that provides computer aid to the task of creating and managing an interoperable federation of systems.

This thesis describes the vision and requirements for this tool along with an initial prototype demonstrating how emerging technologies such as XML and Data Binding are utilized to capture the necessary information required to resolve data representational differences between systems. The material presented in this thesis has the potential to significantly reduce the cost and effort required for achieving interoperability between DoD systems.

VULNERABILITY ASSESSMENT OF MICROSOFT EXCHANGE 2000 SERVER SOFTWARE
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E-mail is the dominant utility in use today as a means of issuing directives and sharing information among employees in most enterprises. Although e-mail is typically not classified, many may be personal, private, or often sensitive in nature. Important information can inadvertently be disclosed that may affect a critical organizational decision. Additionally, the sum of several innocuous e-mail messages may allow malicious agents to infer knowledge that might itself be considered confidential. Exchange Server was selected for this research on the recommendation of the Fleet Information Warfare Center (FIWC) and the National Security Agency (NSA) due to its wide use and importance as the enterprise email solution for the Navy-Marine Corps Intranet (NMCI). A vulnerability assessment was needed in order to ensure a high level of integrity and to ensure the application is deployed in a secure fashion within NMCI. Exchange 2000 Server was found to be extremely functional but insecure primarily due to its clear text messaging, its reliance upon security features of the host operating system, and lack of built-in security features. It is recommended that Microsoft create a better setup program that default to a maximum state of security rather than a state of maximum convenience. It is also recommended that administrators make use of encrypted connections (SSL or VPN for example), phase out pre-Windows 2000 machines, invoke the NSA's published security templates and be diligent in applying vendor supplied patches.

WEB-ENABLING AN EARLY WARNING AND TRACKING SYSTEM
FOR NETWORK VULNERABILITIES
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The Information Assurance Vulnerability Alert (IAVA) process was established to provide an early warning and tracking capability for protecting Department of Defense (DoD) networks against identified system vulnerabilities. The Navy initially used record message traffic for the information distribution required by the process. This approach was heavily administrative and prone to significant delays in an already time critical process. Additionally, it lacked support for automated data validation, resulting in unreliable vulnerability tracking information. As a result, the process was ineffective, and Navy networks remained highly susceptible to exploitation, even for well-documented system vulnerabilities. For this thesis, web-enabling technology is used to build and deploy an early warning and tracking system for Navy network vulnerabilities. The research sponsor, the Navy Component Task Force for Computer Network Defense (NCTF-CND), has named it the Online Compliance Reporting System (OCRS). It is now being

used by all Navy commands and has proven efficient and highly effective in defending Navy networks against known vulnerability exploitations. As a result, the system has gained significant interest from other organizations and the research sponsor is now planning to fund maintenance and future enhancements by the Space and Naval Warfare Systems Center in Charleston, South Carolina.

DESIGN AND IMPLEMENTATION OF ONLINE COMMUNITIES
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There are many claims that building an online community on the Internet is the next big thing for online businesses to enhance their bottom line. Advertising has been the biggest moneymaker on the Internet so far so attention is money on today's Internet. The idea of an online community is to build communication tools into a website to allow visitors to interact with each other and encourage them to return often. By providing visitors with a place to interact with others and talk about their interests companies can better target them with advertising. Certainly a website that brings users back over and over again is very appealing to any organization that is trying to sell goods or get their message heard. But the building of an online community is not as simple as just adding discussion forums and/or chat rooms to a website. In fact, many believe that a successful community is only 10% dependent upon technology and 90% dependent upon people. This thesis takes a look at the principles of successful online communities according to current literature and then analyzes the application of these principles on some popular online communities. It then takes a detailed look at PRESENCE-Lite, an online community built by the author based on the principles of online communities.

THERMINATOR 2: DEVELOPING A REAL TIME THERMODYNAMIC BASED PATTERNLESS INTRUSION DETECTION SYSTEM
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A novel system for conducting non-signature based, or patternless, intrusion detection of computer networks is presented. This system uses principles of thermodynamics to model network conversation dynamics. A notion of baseline operating conditions is developed by observing the properties of entropy, energy and temperature within the system. Perturbations in these properties are considered potential intrusions for further investigation. This thesis focuses on the design and architecture of this system. System functions are decomposed into a network sensing device, a real-time processing component and a forensics component. A mechanism for forwarding and storage of sensed data is developed and discussed. Similarly, a novel three-dimensional display technique and the data structure that allows direct access of raw packet information from energy levels within this display is constructed and discussed. A system configuration language is defined and presented and additional tools for follow-on forensic analysis are developed. Finally, examples of valid intrusions and other network perturbations in real traffic collected in Department of Defense network operation center backbones are presented. Preliminary results indicate this system has significant potential for revealing anomalies in large network systems.

ENHANCING NETWORK COMMUNICATION IN NPSNET-V VIRTUAL ENVIRONMENTS USING XML-DESCRIBED DYNAMIC BEHAVIOR (DBP) PROTOCOLS

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The existing component protocols, as well as new protocols introduced at runtime into NPSNET-V are written in their native programming language. As a result, they require authoring and compiling by a trained programmer. The long time frame required to change or introduce new protocols into NPSNET-V, a dynamically extensible virtual environment, detracts from the dynamics of the virtual environment. Networking optimization thresholds to support NPSNET-V needed to be determined to ensure that the networking is performed efficiently, and system resources to other systems, such as graphics rendering, are maximized. This thesis implements component protocols described using Extensible Markup Language (XML) into NPSNET-V. These protocols are created with different fidelity resolutions for each protocol, which can be swapped at runtime based on the network state. Network testing was performed to find the ideal maximum packet rates based on the impact on CPU utilization and packet loss. By using XML, non-programmers can edit protocols for inclusion in a simulation at runtime.

Important contributions include adding protocols to NPSNET-V with high-resolution and low-resolution versions, described by XML documents. Basic network optimization is added to NPSNET-V to take advantage of the protocols' resolution switching ability. The network testing revealed a linear correlation between the packet sending rate and CPU utilization, and a polynomial correlation between the packet sending rate and percentage packet loss.

SOFTWARE RE-ENGINEERING OF THE HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM - (MAINTENANCE EXTENSION) USING OBJECT ORIENTED METHODS IN A MICROSOFT ENVIRONMENT

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The purpose of this research is to technically evaluate, refine, and expand two existing aircraft safety management information systems (one military and one civilian). The systems are used in the data collection, organization, query, analysis, and reporting of maintenance errors that contribute to Aviation mishaps, equipment damage, and personnel injury. Both programs implement the Human Factors Analysis and Classification System (HFACS) taxonomy model developed by the Naval Safety Center (NSC) to capture aircrew errors in Naval Aviation mishaps. The goal of this taxonomy is to identify areas for potential intervention by fully describing factors that are precursors to aircraft accidents.

Requirements outlined by Dr. John K. Schmidt of the Naval Safety Center, in conjunction with funding by the National Aeronautics and Space Administration, require that the system utilize a Microsoft Access based implementation. This research focuses on meticulous software engineering to investigate the feasibility of adapting the current "structured" systems to Microsoft-based object oriented architectures ensuring future scalability and increased potential for code-reuse.

Primary research questions investigated in this thesis include: 1) How can a Microsoft Access based implementation provide multi-user access to the same database in a client-server environment while ensuring the ability to scale to a large number (potentially thousands) of users? 2) How can the linguistic discontinuity associated with object-oriented concepts and non-object oriented, flat relational databases be overcome when limited by the requirement for a Microsoft Access based solution? 3) The current military

and civilian systems provide similar functionality, but use different database schema. How can object oriented methods be implemented to provide a common interface to both types of data? 4) How should database schema be changed to provide the best performance, scalability, and opportunity for code re-use? 5) In the past, Microsoft has deployed new versions of Microsoft Access and Visual Basic that were not (fully) backwards compatible with previous versions. This caused great discontent among users of applications designed to run under the older versions of these programs. How can our system(s) be designed to isolate them from problems associated with new versions of *Microsoft* products? Specifically, the pending release of Microsoft Office 2002, the new SQL Server 2000 database engine, and Microsoft Visual Basic.NET.

This thesis describes the use of the Spiral Development Model to create a Microsoft-based solution for the School of Aviation Safety requirements. It is hypothesized that this research produced products that greatly enhance current HFACS-capabilities and provide the means to weather further changes in requirements and application platforms.

ELECTRONIC MANEUVERING BOARD AND DEAD RECKONING TRACER DECISION AID FOR THE OFFICER OF THE DECK

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The U.S. Navy currently bases the majority of our contact management decisions around a time and manning intensive paper-based Maneuvering Board process. Additional manning requirements are involved on many Naval Ships in order to accurately convey the information to the Officer of the Deck (OOD) and/or the Commanding Officer. When given situations where there exist multiple contacts, the current system is quickly overwhelmed and may not provide decision-makers a complete and accurate picture in a timely manner.

The purpose of this research is to implement a stand-alone system that will provide timely and accurate contact information for decision-makers. By creating a reliable, automated system in a format that is familiar to all Surface Warfare Officers we will provide the Navy with a valuable decision-making tool, while increasing ease of data exchange and reducing current redundancies and manning inefficient practices.

The software design is based upon the Unified Modeling Language (UML). UML allows us to construct a software model that is supported by the Ada programming language. The design is based upon these fundamental tenants: non-operating system dependent, non-hardware system dependent, extensible and modular design. Ada provides a certified compiler, making the code robust and assuring the "buyer" that the program does what it is advertised to do.

INTEGRATING A TRUSTED COMPUTING BASE EXTENSION SERVER AND SECURE SESSION SERVER INTO THE LINUX OPERATING SYSTEM

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The Multilevel Secure Local Area Network (MLS LAN) Project at the Naval Postgraduate School's Center for Information Security (INFOSEC) Studies and Research (NPS CISR) is building a trusted network system that is both necessary and sufficient to provide a multilevel networking solution for real world use.

The current configuration provides the necessary trusted network services on the TCSEC Class B-3 evaluated XTS-300, which is a combination of the STOP version 4.4.2 multilevel secure operating system, and a Wang-supplied Intel x86 hardware base. The interface for the STOP operating is based on the System V.3 UNIX implementation. System V.3 lacks many of features available in more modern UNIX implementations such as System V.4 and BSD 4.3, and also lacks many of the features in POSIX and ANSI C standards. Finally, the CPU is several generations older than the more current Intel processors. This thesis discusses the port of several MLS trusted network services on the XTS-300 to a Linux operating system running on an Intel Pentium Processor. The new Linux TCBE Server configuration will permit further experimentation with MLS architectural issues in a more modern, flexible and easily modifiable environment. The port was accomplished by identifying and modifying the necessary software modules needed, to adapt to a Linux environment.

This thesis proves that XTS-300 TCB services can be ported to Linux system without any negative effects on performance thus allowing a move toward a more security enhanced implementation.

**THE DESIGN AND DEVELOPMENT OF A WEB-INTERFACE FOR THE SOFTWARE
ENGINEERING AUTOMATION SYSTEM**
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The Software Engineering Automation System (SEAS) evolved from the Computer-Aided Prototyping System (CAPS) developed in the late 1980s and early 1990s to help software engineers rapidly produce working prototypes for hard real-time embedded systems. As software development methods such as the waterfall and spiral methods evolved the requirement for a system to prototype products became clear. CAPS was able to meet the needs of the software engineer, allowing them to edit the project, translate and compile the code, develop the interface, and execute the project. As the requirements change and customer's needs become clearer, the ability to rapidly change the prototype to meet these needs was met by the CAPS system. Today companies that are developing software systems are global in nature. Development could take place over a vast expanse of several continents. The change in the workplace environment bore the requirement to redesign SEAS to make it accessible globally as well as making it functional across multiple platforms. The envisioned redesign of the SEAS system takes the functionality of the current system and deploys it as a web application on the Internet.

**A STUDY OF THE REQUIREMENTS FOR A HEADS-UP DISPLAY FOR USE IN MOTOR
TRANSPORTATION IN THE UNITED STATES MARINE CORPS**
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In this thesis, the high-level requirements for a concept system, Automated Vehicle Avoidance Identification and Location System (AVAILS) is investigated. The primary goal that this system addresses is the safe operation of large ground vehicles, operated by the U.S. Marine Corps and Army, on both military reservations and public roadways. AVAILS is comprised of an integrated collision warning and collision avoidance system. These two subsystems are used to support both low-speed docking and convoy operations. The objective is to provide the driver with real-time information that will help him or her act to avoid or mitigate the effects of a crash with another vehicle during convoy operations, and with another vehicle or the docking facilities during docking operations.

The high-level requirements for the human-computer interface, AVAILS-HCI, are discussed in the context of the following: the characteristics of the drivers, the nature of their tasks, the environment in which ground-based military vehicles operate, and the doctrine, policy, law, regulations, and procedures which govern the operation of such vehicles on military reservations and public roadways. A high-level treatment is given of the mapping of the high-level requirements for the human-computer interface to in-vehicle display technology, in particular, head-up displays. A limited-function prototype of the system was developed in order to explain and reason about the requirements for the AVAILS-HCI. The thesis concludes with recommendations for future research.

USING NETWORK MANAGEMENT SYSTEMS TO DETECT DISTRIBUTED
DENIAL OF SERVICE ATTACKS
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Distributed Denial of Service (DDoS) attacks have been increasingly found to be affecting the normal functioning of organizations causing billions of dollars of losses. Organizations are trying their best to minimize their losses from these systems. However, most of the organizations widely use the Network Management Systems (NMS) to observe and manage their networks. One of the major functional areas of a NMS is Security Management. This thesis examines how the Network Management Systems could aid in the detection of the DDoS attacks so that the losses from these could be minimized. The thesis details the SNMP MIB variables of importance for detecting these attacks and the MIB signatures of the specific attack.

A PATTERN-MATCHING APPROACH FOR AUTOMATED SCENARIO-DRIVEN
TESTING OF STRUCTURED COMPUTATIONAL POLICY
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Organizations are policy-driven entities. Policy bases can be very large and complex; these factors are in the dynamic nature of policy evolution. The mechanical aspects of policy modification and assurance of the consistency, completeness, and correctness of a policy base can be automated to some degree. Such support is known as computer support for policy. An object-oriented schema-based approach to structure policy was developed. The structural model consists of Unified Modeling Language class and collaboration diagrams. The structural model is used by a suite of testing tools. A case study is presented to illustrate the approach to automated testing of policy. The approach to test-case generation is based on the use of patterns within policy statements and relationships between policy objects. The test spectrum has query-specific tests at one end, and the generic types of tests at the other end. The use of statistical inference to reuse test cases is introduced by determining the patterns that approximate the query-to-be-executed. Query mapping, anytime reasoning and fuzzy logic concepts in policies and their applications are discussed

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ADVANCED QUALITY OF SERVICE MANAGEMENT FOR NEXT GENERATION INTERNET
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Future computer networks, including the Next Generation Internet (NGI), will have to support applications with a wide range of service requirements, such as real-time communication services. These applications are particularly demanding since they require performance guarantees expressed in terms of delay, delay jitter, throughput and loss rate bounds. In order to provide such quality-of-service (QoS) guarantees, the network must implement a resource reservation mechanism for reserving resources such as bandwidth for individual connections. Additionally, the network must have an admission control mechanism, for selectively rejecting some QoS-sensitive flow requests based on resource availability or administrative policies.

The Server and Agent-based Active Network Management (SAAM) is a network management system designed to meet the requirements of NGI. In SAAM, emerging services models like Integrated Services (IntServ) and Differentiated Services (DiffServ), and the classical best effort service are concurrently sharing network resources. This thesis develops and demonstrates in SAAM a novel resource management concept that addresses the difficulties posed by QoS networks. With the new resource reservation and admission control approaches, the sharing mechanism is dynamic and adapts to network load. It ensures high resource utilization while meeting QoS requirements of network users.

WEB-BASED TRAINING FOR THE HELLENIC NAVY
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The Hellenic Navy is looking to implement new ways of educating its personnel. Continuous training is a key to improve the performance of personnel. Increased operational tasks are preventing participation of a large portion of active military personnel in traditional classroom seminars and courses. Distance learning is a solution, which eliminates the need for the physical presence of a student in a classroom. New means of communication such as computer networks can deliver a large amount of information practically to any place in the world. Those against distance learning methods claim that the quality of distance learning courses is not equivalent to that of a traditionally taught course. In our work, the same course was taught both in a classroom and on the Web. The performance of the students in the classroom was compared to those taking the course online. Specific design principals were used for the Web site in order to achieve the best interface to deliver the course material.

PRINCIPLES FOR WEB-BASED INSTRUCTION
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This thesis presents a set of principles for web-based instruction based on literature from instructional design, usability engineering, and human-computer interaction. A questionnaire based on usability and instructional design attempts to show that in order to improve web-based instruction, usability and instructional design need to be taken into consideration when constructing long distance courses via the Web. The results show that usability and instructional design are dependent upon each other in order to present an effective on-line course while simultaneously learning from it.

WEB DATABASE DEVELOPMENT
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This thesis explores the concept of Web database development using Active Server Pages (ASP) and Java Server Pages (JSP). These are among the leading technologies in the web database development. The focus of this thesis was to analyze and compare the ASP and JSP technologies, exposing their capabilities, limitations, and differences between them. Specifically, issues related to back-end connectivity using Open Database Connectivity (ODBC) and Java Database Connectivity (JDBC), application architecture, performance, and web security were examined. For demonstration purposes, two applications were developed, one with ASP and another with JSP. The user interface and the functionality of these two applications were identical, while the architecture, performance, and back-end connectivity was totally different.

IMPLEMENTATION OF A MULTI-AGENT SIMULATION FOR THE NPSNET-V VIRTUAL ENVIRONMENT RESEARCH PROJECT
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Traditional networked military simulation systems are technologically frozen the moment they are completed, thus limiting the participants that can interact in the simulation. When training for urgent missions in emerging conflict areas, assimilating new models, threat behaviors, and new terrain environments into the simulators requires lengthy integration, is prohibitively costly, and is non-distributable electronically at runtime. Threat behaviors are pre-scripted, lack organization, and do not accurately portray doctrine or rules-of-engagement.

NPSNET-V is a novel architecture for networked simulations that supports scalable virtual worlds with built-in dynamic entity loading. These advances address each of the above concerns: scalability, entity and environment distribution, and dynamic technology loading. By combining this architecture with a system for creating autonomous, adaptable agents, threat forces can be accurately simulated. This architecture is useful for proposing designs for strategies, tactics, or force packages during the conduct of experiments.

The result of this thesis is a proof-of-concept application demonstrating the utility of these architectural advances. In this application, numerous autonomous agents form complex, dynamic, and adaptable interactions with resident and remote heterogeneous entities. These results define the course for future military models and simulations.

FAULT TOLERANCE IN THE SERVER AND AGENT BASED NETWORK MANAGEMENT (SAAM) SYSTEM
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Interconnected networks of computers are becoming increasingly important. It is the Internet that has spurred the most recent growth in global computer networks. The limitations of the Internet can be blamed on many factors but when determining solutions to these shortcomings the focus has been on replacing the current Internet Protocol version 4 (IPv4) with the new Internet Protocol version 6 (IPv6). Much work has

been done and much more work remains to be done in transitioning to and reaping the benefits of this "Next Generation Internet." The Server and Agent Based Active Network Management (SAAM) project is one of many "Next Generation Internet" projects that intend to implement and exploit the enhanced capabilities of IPv6 to overcome the limitations of the current Internet. The focus of the SAAM project is guaranteed quality of service (QoS). This thesis addresses fault tolerance in a SAAM region with regards to router and link failures. A hybrid link restoration (rerouting) scheme is proposed, in which central knowledge (at the SAAM server) of the network topology is used to develop alternate paths while path switching is done at a local (router) level.